

1 WHAT IS CLAIMED IS

5

1. A laser diode, comprising:

a substrate of a first conductivity type;

a first cladding layer having said first conductivity type, said first cladding layer being

10 formed on said substrate epitaxially;

a first optical waveguide layer formed epitaxially on said first cladding layer;

an active layer of a group III-V compound semiconductor material formed epitaxially on said first

15 optical waveguide layer;

a second optical waveguide layer formed epitaxially on said active layer;

a second cladding layer having a second, opposite conductivity type, said second cladding layer

20 being formed on said second optical waveguide layer epitaxially;

a first electrode injecting first type carriers having a first polarity into said active layer; and

25 a second electrode injecting second type

09391472-090899

1 carriers having a second, opposite polarity into said
active layer,

said active layer having a composition of
GaInNP containing therein N as a group V element.

5

2. A laser diode as claimed in claim 1,
10 wherein said laser diode further including, between said
first optical waveguide layer and said active layer, an
intermediate layer of a group III-V compound
semiconductor material substantially free from Al and N
in intimate contact with said active layer.

15

3. A laser diode as claimed in claim 2,
20 wherein said active layer forms a type-I heterojunction
with said intermediate layer.

25

09391472-090899

5

15

25

7. A laser diode as claimed in claim 2,

1 wherein said intermediate layer is formed of either of a
binary compound or a ternary compound.

5

8. A laser diode as claimed in claim 2,
wherein said intermediate layer has a composition that
achieves a lattice matching with said substrate.

10

9. A laser diode as claimed in claim 2,
15 wherein said intermediate layer has a composition that
accumulates a strain therein.

20

10. A laser diode as claimed in claim 2,
wherein said intermediate layer is formed of GaInP.

25

09391472.090899
668060" 2476360

1 14. A laser diode as claimed in claim 2,
wherein said active layer has an MQW structure including
an alternate stacking of a plurality of quantum well
layers of GaInNP and a plurality of barrier layers, said
5 MQW structure further including, at a bottom surface of
each of said quantum well layers, another intermediate
layer in intimate contact with said quantum well layer,
said another intermediate layer having a composition
substantially identical with a composition of said
10 intermediate layer.

15 15. A laser diode as claimed in claim 14,
further including, at a top surface of each of said
quantum well layers, a further intermediate layer in
intimate contact with said quantum well layer, said
further intermediate layer having a composition
20 substantially identical with said composition of said
intermediate layer.

1 16. A laser diode as claimed in claim 3,
 wherein said active layer accumulates therein a
 compressive strain.

5

 17. A laser diode as claimed in claim 3,
 wherein said active layer accumulates therein a tensile
10 strain.

15 18. A laser diode as claimed in claim 3,
 wherein said active layer is doped to a p-type.

20

 19. A laser diode as claimed in claim 3,
 wherein said intermediate layer is doped to an n-type.

25

09391472-090899
658060" 244660

1 20. A laser diode as claimed in claim 2,
wherein said intermediate layer includes, at a top
surface thereof contacting said active layer, a layer
containing N as a group V element.

5

21. A vertical-cavity laser diode,
comprising:

10 a substrate having a first conductivity type;
a first optical reflector provided on said
substrate;

15 a first cladding layer having said first
conductivity type on said first optical reflector in an
epitaxial relationship with said substrate;

 a first optical waveguide layer formed
epitaxially on said first cladding layer;

20 an active layer of a group III-V compound
semiconductor material formed epitaxially on said first
cladding layer;

 a second optical waveguide layer formed
epitaxially on said active layer,

25 a second cladding layer having a second,
opposite conductivity type on said active layer in an
epitaxial relationship with said second optical

09361472-000899
668060-247660

1 waveguide layer;

a second optical reflector provided on said
second cladding layer;

a first ohmic electrode provided in ohmic
5 contact with said substrate; and

a second ohmic electrode provided in ohmic
contact with said second cladding layer;

said active layer having a composition of
GaInNP containing therein N as a group V element.

10

22. A vertical-cavity laser diode as claimed
in claim 21, wherein each of said first and second
15 optical reflectors comprises a semiconductor multilayer
mirror.

20

23. An optical disk drive, comprising:

a spindle motor adapted to be mounted with an
optical disk, said spindle motor rotating said optical
disk mounted thereon; and

25 an optical pickup focusing an optical beam on

09391472-090899

- 1 a recording surface of said optical disk mounted on said spindle motor,
- said optical pickup including a vertical-cavity laser diode comprising:
- 5 a substrate having a first conductivity type;
- a first optical reflector provided on said substrate;
- a first cladding layer having said first conductivity type on said first optical reflector in an
- 10 epitaxial relationship with said substrate;
- a first optical waveguide layer formed epitaxially on said first cladding layer;
- an active layer of a group III-V compound semiconductor material formed epitaxially on said first
- 15 optical waveguide layer;
- a second optical waveguide layer formed epitaxially on said active layer;
- a second cladding layer having a second, opposite conductivity type on said second optical
- 20 waveguide layer in an epitaxial relationship with said active layer;
- a second optical reflector provided on said second cladding layer;
- a first ohmic electrode provided in ohmic
- 25 contact with said substrate; and

09391472.000899

1 a second ohmic electrode provided in ohmic
contact with said second cladding layer;
 said active layer having a composition of
GaInNP containing therein N as a group V element.

5

24. An optical transmission system including
10 an optical transmitter and a plastic optical fiber
coupled optically with said optical transmitter, said
optical transmitter including a vertical cavity laser
diode comprising:

 a substrate having a first conductivity type;
15 a first optical reflector provided on said
substrate;

 a first cladding layer having said first
conductivity type on said first optical reflector in an
epitaxial relationship with said substrate;

20 a first optical waveguide layer formed on said
first cladding layer epitaxially;

 an active layer of a group III-V compound
semiconductor material formed epitaxially on said first
optical waveguide layer;

25 a second optical waveguide layer formed on

09391472.090899

1 said active layer epitaxially;
 a second cladding layer having a second,
opposite conductivity type on said second optical
waveguide layer in an epitaxial relationship with said
5 active layer;
 a second optical reflector provided on said
second cladding layer;
 a first ohmic electrode provided in ohmic
contact with said substrate; and
10 a second ohmic electrode provided in ohmic
contact with said second cladding layer;
 said active layer having a composition of
GaInNP containing therein N as a group V element.

15

25. A method of fabricating a compound
semiconductor device, comprising the step of:

- 20 (a) forming a first group III-V compound
semiconductor layer epitaxially on a substrate;
 (b) exposing a surface of said first group
III-V compound semiconductor layer to an atmosphere
containing N;
25 (c) forming, after said step (b), a second

039142-090899
668060-247660

1 group III-V compound semiconductor layer on said first
group III-V compound semiconductor layer epitaxially,
said second group III-V compound semiconductor layer
containing therein N as a group V element,

5 wherein said atmosphere is substantially free
from a group III element.

10

26. A method as claimed in claim 25, wherein
said atmosphere contains an organic nitrogen compound
and a source gas of a group V element other than N.

15

27. A method as claimed in claim 25, wherein
said atmosphere contains DMHy.

20

28. A method as claimed in claim 27, wherein
25 said step of exposure is conducted at a temperature of

09391472-090899
668060-22476260

1 about 600°C.

5

29. An optical semiconductor device,
comprising:

a substrate;

a first layer of a III-V compound

10 semiconductor material formed on said substrate
epitaxially, said first layer being substantially free
from N;

an active layer of a III-V compound
semiconductor material formed on said first layer
15 epitaxially in intimate contact therewith, said active
layer containing N as a group V element;

a second layer of a III-V compound
semiconductor material formed on said active layer
epitaxially in intimate contact therewith, said second
20 layer being substantially free from N,

an interface between said first layer and said
active layer contains C.

25

09391472-090899
658060-2476660

1 30. A semiconductor layered structure,
comprising:

 a first epitaxial layer of AlGaInNP having a
composition represented by compositional parameters x_1 ,
5 y_1 and z_1 ($0 \leq x_1 < 1$, $0 < y_1 \leq 1$, $0 < z_1 < 1$) as

$\text{Al}_{x_1}\text{Ga}_{y_1}\text{In}_{(1-x_1-y_1)}\text{N}_{z_1}\text{P}_{(1-z_1)}$;

 a second epitaxial layer of AlGaInP having a
composition represented by compositional parameters x_2
and y_2 as $\text{Al}_{x_2}\text{Ga}_{y_2}\text{In}_{(1-x_2-y_2)}\text{P}$, said second epitaxial
10 layer being disposed adjacent to said first epitaxial
layer; and

 a third epitaxial layer of AlGaInP having a
composition represented by compositional parameters x_3
and y_3 as $\text{Al}_{x_3}\text{Ga}_{y_3}\text{In}_{(1-x_3-y_3)}\text{P}$, said third epitaxial
15 layer being disposed between said first and second
epitaxial layers, said first through third epitaxial
layers maintaining an epitaxy with each other;

 wherein said compositional parameters are set
so as to satisfy the relationship:

20 $0 \leq x_3 < x_2 \leq 1$; $0 < y_3 \leq 1$.

25 31. A semiconductor light-emitting device,

1 comprising:

a substrate of a first conductivity type;

a first cladding layer of AlGaInP of said
first conductivity type provided on said substrate;

5 an active layer of undoped AlGaInNP provided
on said cladding layer; and

a second cladding layer of AlGaInP of a
second, opposite conductivity type provided on said
active layer;

10 said active layer having a composition
represented by compositional parameters x_1 , y_1 and z_1 as
 $\text{Al}_{x_1}\text{Ga}_{y_1}\text{In}_{(1-x_1-y_1)}\text{N}_{z_1}\text{P}_{(1-z_1)}$ ($0 \leq x_1 < 1$, $0 < y_1 \leq 1$, $0 < z_1 < 1$), said first cladding layer having a composition
represented by compositional parameters x_2 and y_2 as

15 $\text{Al}_{x_2}\text{Ga}_{y_2}\text{In}_{(1-x_2-y_2)}\text{P}$,

wherein there is provided an intermediate
layer of AlGaInP between said first cladding layer and
said active layer, said intermediate layer having a
composition represented by compositional parameters x_3 ,

20 y_3 and z_3 as $\text{Al}_{x_3}\text{Ga}_{y_3}\text{In}_{(1-x_3-y_3)}\text{P}$,

said compositional parameters satisfying the
relationship:

$$0 \leq x_3 < x_2 \leq 1; 0 < y_3 \leq 1.$$

25

09391472-090899

1 32. A semiconductor light-emitting device as
claimed in claim 31, wherein said intermediate layer has
a composition represented by a compositional parameter
y4 as $\text{Ga}_{y4}\text{In}_{(1-y4)}\text{P}$ ($0 < y4 < 1$).

5

33. A semiconductor light-emitting device,
10 comprising:
a substrate of a first conductivity type;
a first cladding layer said first conductivity
type provided on said substrate;
a first optical waveguide layer of undoped
15 AlGaInP provided on said first cladding layer;
an active layer of undoped AlGaInNP provided
on said optical waveguide layer;
a second optical waveguide layer of undoped
 AlGaInP provided on said active layer; and
20 a second cladding layer of a second, opposite
conductivity type provided on said second optical
waveguide layer
said active layer having a composition
represented by compositional parameters x1, y1 and z1 as
25 $\text{Al}_{x1}\text{Ga}_{y1}\text{In}_{(1-x1-y1)}\text{N}_{z1}\text{P}_{(1-z1)}$ ($0 \leq x1 < 1$, $0 < y1 \leq 1$, 0

1 < $z_1 < 1$), said first optical waveguide layer having a
composition represented by compositional parameters x_2
and y_2 as $Al_{x_2}Ga_{y_2}In_{(1-x_2-y_2)}P$,

wherein there is provided an intermediate
5 layer of AlGaInP between said first optical waveguide
layer and said active layer, said intermediate layer
having a composition represented by compositional
parameters x_3 and y_3 as $Al_{x_3}Ga_{y_3}In_{(1-x_3-y_3)}P$,

said compositional parameters satisfying the
10 relationship:

$$0 \leq x_3 < x_2 \leq 1; 0 < y_3 \leq 1.$$

15

34. A semiconductor light-emitting device as
claimed in claim 33, wherein said intermediate layer has
a composition represented by a compositional parameter
 y_4 as $Ga_{y_4}In_{(1-y_4)}P$ ($0 < y_4 < 1$).

20

35. A method of fabricating a semiconductor
25 layered structure comprising a first epitaxial layer of

06391472.090899
658060" 2476660

1 AlGaInNP having a composition represented by
compositional parameters x_1 , y_1 and z_1 as $\text{Al}_{x_1}\text{Ga}_{y_1}\text{In}_{(1-x_1-y_1)}\text{N}_{z_1}\text{P}_{(1-z_1)}$ ($0 \leq x_1 < 1$, $0 < y_1 \leq 1$, $0 < z_1 < 1$), a
second epitaxial layer of AlGaInP having a composition
5 represented by compositional parameters x_2 and y_2 as
 $\text{Al}_{x_2}\text{Ga}_{y_2}\text{In}_{(1-x_2-y_2)}\text{P}$, said second epitaxial layer being
disposed adjacent to said first epitaxial layer, and a
third epitaxial layer of AlGaInP having a composition
represented by compositional parameters x_3 and y_3 as
10 $\text{Al}_{x_3}\text{Ga}_{y_3}\text{In}_{(1-x_3-y_3)}\text{P}$, said third epitaxial layer being
disposed between said first and second epitaxial layers,
said first through third epitaxial layers maintaining an
epitaxy with each other, said compositional parameters
being set so as to satisfy the relationship $0 \leq x_3 < x_2$
15 ≤ 1 ; $0 < y_3 \leq 1$,
said method comprising the steps of:
forming said first epitaxial layer by using a
metal organic compound of Al for the source of Al;
forming said second epitaxial layer by using a
20 metal organic compound of Al for the source of Al; and
forming said third epitaxial layer by using a
metal organic compound of Al for the source of Al.

1 36. A method as claimed in claim 35, wherein
said step of forming said first epitaxial layer is
conducted further by using an organic compound of N as
the source of N.

5

10 37. A method as claimed in claim 36, wherein
said organic compound is selected from one of
dimethylhydradine and monomethylhydradine.

15

20

25

09391472 090899
668060 247660